# MODULAR BIOMASS POWER PLANT FEASIBILITY STUDY

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# Credits

Lumberjack RC&D is a 501(c) 3 rural/urban development council whose mission is to:

- Support and promote enhancement of the quality of the environment, thereby providing an attractive and satisfying place to live and work.
- Protect, preserve, restore, and where necessary, improve land, water, and related resources to assure the quality of the natural resource base for sustained use.
- Support and promote a better living standard and adequate income for area citizens through social, economic, and natural resource development.
- Foster relationships between public and private sectors to provide maximum benefit to area citizens.

As a part of this mission, Lumberjack RC&D obtained a Rural Community Assistance grant through the USDA Forest Service. The purpose of this study is to determine the feasibility of "Modular Biomass Power Plants" in the Lake States (Michigan, Minnesota, and Wisconsin).

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# Overview of Modular Biomass Power Plant Systems

Biomass electrical energy/thermal production, also known as cogeneration (the production of electricity and thermal energy simultaniously from a common fuel source), is not *the* answer to America's energy needs; however, it can be an answer to specific situations where several factors come together and make biomass energy generation an attractive option.

These factors may vary, but could include:

- Communities that are isolated from a ready or adequate power source.
- Situations where excess thermal energy can be used in commercial situations.
- A ready, comparatively cheap biomass fuel supply.
- Renewable energy credits [xiv] and other potential incentive programs.

*Biomass Pros*

*Opportunity*[i]

- Modular power plants can improve power quality on weak transmission lines located far from central transmission plants
- Potential opportunities for modular biomass power plants would be sawmills with kilns or food processing plants with high-energy crops and stockpiles of offal (cornhusks, rice hulls, etc.)

*Environmental Benefits*[i]

- Biomass combustion is considered $CO_2$ neutral so it is not considered a major producer of greenhouse gas linked to climate change
- It is not a major contributor of acid rain due to negligible sulpheric outputs

*Monetary Benefits*

- Biomass fuel is available in the Lake States
- Potential renewable energy credits[i] (Appendix 1)
- Economics of wood waste energy generation becomes more attractive as traditional fuel prices increase[i]
- Disposal costs for some wood waste[i]

*Local Economic Benefits*[i]

- Generated locally , biomass generated money stays in the local economy
- Collection, preparation, and delivery of biomass fuel involves greater labor output than fossil fuels
- Improves local tax base and building tax revenue
- A value added product is realized by the collecting, processing, and transporting woody biomass. This is more labor intensive than fossil fuel delivery, thus creating a direct economic impact on local employment and having an indirect economic impact throughout the local economy

*Biomass Cons*

Biomass systems are larger and often require access for direct truck delivery of fuel, space for fuel storage, and a larger boiler room to house mechanical fuel delivery and ash removal systems.

Biomass materials are generally not standardized, universal, or consistent fuels that are backed by a large national supplier. As a result, consistency and supply reliability become a concern. The energy content varies significantly depending on the type of biomass used for fuel. In addition, a biomass plant requires more frequent maintenance and greater operator attention that that of conventional systems (gas/oil systems). The degree of operator dedication to the system is critical to its success.

The initial capital costs and operational/maintenance costs are generally higher than that of other systems. Biomass systems, as compared to gas as an example, have a much narrower range of reasonably efficient operation (i.e. if the load is too low there will be a smoke problem – hence it is difficult to size a max seasonal requirement if the seasonable load varies. Therefore, this is why wood generally needs a backup system).

*Synopsis*

Biomass cogeneration systems, and in particular small (less than 5 Megawatt) modular biomass cogeneration systems, can fit in nicely and very efficiently within the energy makeup of many communities, small or large, rural or urban. They can make a serious difference in the costs of electrical power, "clean" waste disposal, and thermal energy (steam, hot water, absorption chilling, etc.). Properly designed, properly installed, and properly maintained biomass cogeneration systems can be an important source of reliable renewable energy.

The very first question that should be asked when considering a biomass cogeneration system is whether this is the right fit for the specific need. The concept has to be properly planned out and has to make sense from an economic, energy need, and environmental standpoint. To ensure that a cogeneration power plant would be the most efficient addition to the industrial park or community, proper engineering is essential.

More electricity and heat are generated for a lesser amount of fuel by a cogeneration system as compared to separate heat and power units. Common challenges for all wood-fired systems are ensuring adequate fuel supply and effectively dealing with fuel handling and storage issues.

## Modular Biomass Power Plant Feasibility Study

**Equipment Information**

This study focuses on the concept of small, modular, packaged systems that would be built and installed in approximately 1 Megawatt size configurations. The concept being, if energy needs were to increase, additional modules could be added to the system. The concept works best in the 1-4 Megawatt range. Anything larger than that should be addressed by a different technology approach, such as using a single boiler array with a high-pressure condensing turbine or a bottoming cycle gas turbine (Integrated Gasification Combined Cycle) for power generation.

This study will focus on the design, production, and installation of modular biomass systems in the 1-2 Megawatt range. Multiple units (2-4) could be installed in tandem to create a total output up to 4 Megawatts worth of power.

Two manufacturers of modular biomass equipment are featured in this study. [ii] One company is KMW®, which is located in London, Ontario, Canada. The other company is Hurst Boiler & Welding Company, Inc., which is located in Coolidge, Georgia.

For information regarding the boiler systems, refer to the web sites for KMW® www.kmwenergy.com and Hurst www.hurstboiler.com.

For information regarding backpressure turbines referred to in this document, access the Turbosteam web site, www.turbosteam.com[iii]. Turbosteam, located in Turners Falls, MA, is not a manufacturer of boiler systems but rather a packager of backpressure turbine systems, a critical component of the biomass cogeneration system that is being discussed.

These three company web sites will provide a wealth of information regarding small biomass cogeneration operations.

Each of the two boiler companies (KMW® and Hurst) has the ability to package small biomass cogeneration systems (< 2 Megawatts).

The 1 Megawatt option allows the host site to add capacity as it needs to in an affordable manner and thereby allows each system to operate at its maximum efficiency level. You do not want to build a 3 Megawatt system and "low fire" it because you only have a need for 2 Megawatts worth of energy. Keep it simple.

In keeping with the concept of modular biomass systems, the 1 Megawatt system would be sold as an easily transportable packaged unit. The system would be built in a minimal amount of sections (five to seven) at the factory. The sections would be transported to the job site and field assembled. Larger biomass systems (5 megawatts or greater) are typically built on site, piece by piece, and are not packaged systems.

The building needs of the biomass facility will be dependent upon the planned number of modules that the building would need to house. A facility does not necessarily have to install all of the modules at one time, but the building should be large enough to accommodate future module expansion (i.e. you can install a pair of 1 Megawatt units beside one other and leave space for an additional unit(s) to be added later).

If there is any potential for the future addition of more modular units, mechanical design layout is critical from the beginning to allow for the additional electrical and thermal power that would be generated. Detailed engineering that allows for this is critical from the early planning stages of the project.

**Needs Assessment**
Is there an adequate physical location for the system?
Is an appropriate fuel supply available?
Is there a need for the electrical power that would be generated?
Is there a need for the thermal energy that would be created?
Is there an outlet for the ash that would be produced by the system?
Moreover, the most important question that has to be asked is:
Can the host site utilize the thermal energy that will be produced on a perpetual or nearly perpetual basis?

If the thermal energy cannot be utilized productively for more than half the hours of a day, approximately 5,000 hours per year, the project may not be economically feasible. The project needs a demand for the thermal energy. The electrical power should be supplementary, as the thermal energy needs to be the drive behind the project.

If all of these questions can be answered with a yes, and all conditions point towards the viability of a small biomass cogeneration system, the modular or packaged systems are worth considering.

**Location Factors**
Many factors need to be considered in selecting a modular biomass power plant location, including:

- Size of the plant
- Access to a fuel and water supply
- Location of existing electric transmission lines and substations
- Land availability
- Existing air and water quality at the site
- Total cost of construction at the site
- Availability of nearby thermal energy/low-pressure steam users
- If appropriate, surrounding land use

These factors and public input need to be carefully reviewed and used as the basis for choosing sites.

**Potential Applications**
Ideally, biomass systems should be installed in locations that could take advantage of the thermal energy produced via the cogeneration. An industrial park in a rural community with a wood industry that has a steady stream of wood waste and dry kilns or other processes that would require thermal energy would be an ideal location/situation for a modular biomass power plant. However, this does not mean that it has to be a use that is directly related to forest industry, such as the dry kiln example. The thermal energy produced could be used for a number of heating applications, including many types of manufacturing, ethanol producers, food products processors with process heat requirements, and some seasonal energy users such as commercial greenhouses, correctional facilities, school systems, hotels, hospitals, and waste treatment centers.

Low-pressure steam could also be used for dehumidification processes or even air conditioning, via steam or hot water absorption chillers. One ideal scenario that could be created is a community owned biomass cogeneration system. The system could produce energy that would heat and dehumidify an indoor pool and/or an indoor community ice arena. The biomass system, community pool, and community ice arena could all be built adjacent to each other on community property and have a symbiotic working relationship regarding the creation and effective uses of energy.

The community system is just one small example. The point is to make certain the biomass system being built will have a mission and that it can be sustained for the long-term in regards to both supply and demand, supply in regards to adequate quantity of reasonably priced biomass fuel and demand in regards to thermal energy use.

**Determining Plant Size and Scale**

Larger systems can provide greater economies of scale in the right situation. It can cost the same to staff a small biomass system as it would a large biomass system. So why not build the largest system that you can to achieve those economies? Simply put, the economic feasibility of a biomass energy system is usually directly related to a local source of fuel.

As stated previously, make the thermal energy drive the project. In many cases, the “break-even” point can be achieved on electrical power by itself; however, the cost efficiencies and the system efficiencies are going to be directly related to maximizing the use of the thermal energy that is produced. You want to be able to put a project together that can demonstrate as high an operation efficiency as possible, with 80-85% efficiency being the top end. You cannot do that if you do not use as much of the thermal energy as possible. If you are blowing thermal energy into the atmosphere, you are wasting potential plant income. You are not looking to build a merchant power plant (a plant set up strictly for the purpose of generating electrical power and selling that electrical power to the utility grid); you are looking to build the most efficient, cost effective energy system that you possibly can. The economies of scale that may be achieved by building a larger system could be completely washed out by fuel supply shortages and/or excess thermal energy.

Being able to manage the fuel supply and capital expenses of the project, as well as being able to utilize the thermal energy created are all critical ingredients that will lead to a successful plant project. Small modular systems lend themselves very well to these conditions. Another advantage to the modular system is the ability to add on another unit if the demand for electrical/thermal energy increases and an adequate fuel supply is obtainable.

*Building/Site Needs*

A number of building types will accommodate this modular system; however, typical steel buildings (prevalent in industrial parks nationwide) would work just fine for a biomass operation. These buildings can be custom designed to meet the needs of the particular installation and have proven to be very cost effective.

A 1 Megawatt system consisting of a pair of 600 HP boilers and a single backpressure turbine would require a footprint of no more than 5000 sq ft. A pair of 600 HP boilers are recommended rather than one 1200 HP system, because a pair will allow one boiler to be serviced while the other remains operational. In addition, in periods where less energy is required, it is much more economical to run a single 600 HP system than trying to low fire a 1200 HP unit.

The building would need to have a height clearance of approximately 30 feet to allow for the exhaust and steam piping that would be installed above the cogeneration system. The building should also be constructed so that the back panel (made of sheet steel) can be removed temporarily to allow equipment to be brought in or out with minimal disruption.

In addition to the actual building space needed to house the power plant, supplementary space will be needed for fuel storage (which may or may not be in the same building as the power plant unit) and adequate space around the building will be necessary for semi-truck delivery of fuel chips.

Adequate water supply to the site will be needed, which can be achieved by a well system or a city/township water system. If water quality is an issue (i.e. the water has high mineral content or other water quality issues), a filtration system may be needed. There are many variables for usage in this type of unit, but for a rule of thumb, on a 1 Megawatt unit, 9-10 gallons of water per minute would be needed.

Accessibility to the existing power grid is also essential when determining plant location.

**Fuel Requirements**

Working with the concept of keeping things as simple as possible, the biomass cogeneration system could be designed to use a variety of biomass fuels, with varying physical attributes.

*Source and Cost Considerations*

The cost of biomass fuels can vary depending on circumstances such as source, location, quality, other potential users for the fuel, and normal conditions of supply versus demand.

Biomass waste fuel, such as mill residue (also known as forest industry processing wood waste), is usually the lowest-cost option. In the absence of waste sources, logging residue collected from near the biomass facility might prove to be a cost-effective option.

The costs for biomass fuel will depend on the price paid for an alternative use of the biomass (i.e. additional value-added markets being created for products primarily used as biomass). Long-term contracts with fuel suppliers are therefore important due to the laws of supply and demand and the ever-evolving economic value of biomass products[i].

*Wood Fuel Types*

Wood fuel in the form of sawdust, ground pallets, ground crates, whole tree chips, logging residue chips, and/or bark could be blended together to make a clean wood fuel for the biomass system. The type of fuel mix that can be handled can vary by manufacturer, therefore; fuel mixes should be discussed with the manufacturer to ensure proper performance of the system. The ash produced by the combustion of these clean wood fuels could be used as an organic fertilizer, another beneficial byproduct of the process.

Construction and demolition debris (c&d) can be (and is) used as a commercial biomass fuel. In the state of Maine, a number of merchant biomass electric power generators use c&d for as much as 50% of their fuel mix. The c&d that is used for feedstock fuel has been professionally sorted at recycling centers. Sorting is supposed to remove metal, glass, plastic, lead painted wood, arsenic treated wood, concrete, and all other non-wood based products from the potential fuel pile. Even the best processing still leaves some volatile material mixed in with the wood. The sorted c&d material is ground into a shredded consistency, sifted, sometimes washed (depending upon the processor), and is then considered fuel ready. The resultant ash that the c&d produces must be handled as a hazardous waste. In addition, due to the contaminants that could be inherent in the c&d mix, the permitting guidelines for plants that burn c&d are much stricter.

A biomass plant burning a variety of clean waste wood fuels should have little to no difficulty in achieving favorable stack emissions. When you start adding contaminant-laden fuel into the scenario however, the process could become more complicated. Many small biomass operations shy away from fuels such as c&d and concentrate on clean waste fuel whenever possible.

*Other Biomass Fuel Sources*

Non-woody biomass feedstock that could be used by themselves or mixed with other fuels includes cornhusks, switchgrass, waste paper, straw, and a number of agricultural offal's (sunflower seed hulls, nutshells etc.).

*Chip Requirements*

“Variable” is a key factor when choosing options for biofuel sources. Unlike fossil fuels, there is usually no certain supply for a guaranteed amount of time. Additionally, care must be taken to ensure that there are options open as quality may vary between sources, year-to-year, or even between deliveries. It is recommended to have fuel specifications carefully and specifically outlined.

A specific wood chip size (a requirement for some biomass systems) and design (an issue for a number of specialty wood fuel gasification systems) are not issues for the modular units that are being discussed. Generally, anything less than a 2-inch chip should work fine in either of the systems.

*Moisture Content*

The lower the moisture content of the fuel the greater the heat value of the fuel and, consequently, the efficiency of the operation is improved (Appendix 2). A reasonable expectation would be to have a fuel mix in the 30 to 35% (30-35% of total weight is water) wet basis moisture content range. The particular biomass systems that we are discussing could operate with fuel mixes in the 50% moisture content range or greater (60%+, fire usually cannot be maintained). Biomass fuel is bought and sold by the ton and, in many cases; no allowance is made for moisture content. Therefore, a contractor is being paid less for delivering higher BTU fuel because as the moisture content goes down, so does the weight and most biomass chips are sold on a per ton basis. Developing a system for a higher payment based on lower moisture content would be of considerable help in both making these plants more efficient and cost effective and in giving suppliers incentive to deliver fuel supplies that have a lower moisture content.

Moisture content, in regards to operating constraints, is not as critical an issue as it once was when fuel had to be at a much lower moisture content percentage than what is currently acceptable for most boiler units. However, lower moisture content will yield more BTU's per ton. For example, fuel that has 50% moisture content is 50% water and much of the potential BTU's will be lost evaporating that water from the wood. Therefore, lowering the moisture content will improve the efficiency of the biomass plant.

In small capacity modular biomass plants, the moisture can interfere with the effectiveness of the oxidation process, leading to higher emissions of carbon monoxide and unburned hydrocarbons. Wet fuels can be burned without additional emissions, however, only in high temperature applications.

*Delivery and Storage*

Unless generated on-site, the biofuel will normally be delivered by truck. Each option will have an impact on the layout of the system. Delivery can be by:

- Self-unloading truck or trailer (i.e. walking floor)
- Ramp or dumping station

Storage options for the biofuel are:

- Particulate fuels are either piled on the floor in an above-ground building or placed in dedicated storage facilities, such as above-ground concrete burrows.

**Operational Requirements**

The concept of simplicity is the basis behind modular biomass power plants. The whole idea is that a small, carefully planned, and carefully installed biomass system can have a substantial impact on the energy make up of many communities and businesses.

As a general rule, depending upon the state and the location of the project, most of the following items would have to be performed before any power plant would be allowed to start up and operate:

- Site evaluation
- Land use evaluation
- Storm water run off evaluation and planned remediation
- Emissions permitting
- Ash disposal plan
- Hazardous waste disposal plan
- Interconnection study for hookup to the utility grid

There will be a combination of issues that would have to be addressed on the state and local community level. How the plant would integrate into the local utility grid makeup is a regional issue. Working closely with state regulators and the representatives of the local utility will be absolutely essential.

*Permitting and Regulatory Issues*

Regarding the permitting and regulation of any biomass cogeneration plant no matter what its size is, there will be a number of issues that will have to be addressed. However, they are all very doable and can be accomplished with the right team in place.

Local and state permits/regulations can vary, therefore, this is not meant to be an all-inclusive list for each specific state but rather a list to give you an idea of what issues to be aware of and what level of government would typically be responsible. Entities at the federal, state, and local level should be contacted to get a specific lists of permits needed to start a modular biomass plant in your area.

**State:**

- Storm Water - Initial construction permits as well as potential operational permits
- Water Supply - Related to volume of water required and number of employees
- Waste Water
- Solid and Hazardous Waste - Related to daily activities through process waste, such as ash disposal
- Air Quality
- Water Regulations – lakes, streams, and/or wetlands involvement
- Environmental Assessments - these actions are typically only taken with facilities of very large size or impact

**Local Government:**

- Zoning
- Water Regulation Issues
- Municipal Water Supplies

**Federal**

- Air Quality - Environmental Protection Agency (EPA)
- Wetlands - Army Corps of Engineers
- Energy Generation - Federal Energy Regulatory Commission (FERC)

*Start-up, Commissioning, & Performance Tests*

Start-up and commissioning of a modular biomass plant system should be the responsibility of the contractor (manufacturer or supplier). This involves[i]:

- Mechanical test of all components
- First actual firing and operation of the unit
- Initial test period for adjustments, tuning, and possible minor modifications

Performance tests may also be carried out separately to establish that the performance criteria, such as emissions, efficiency, turndown, and response can be met. The lowest quality fuel that meets the system's guarantee criteria should be used for commissioning and performance testing [i].

*Assessing Costs* [i]

Annual costs are the expenses incurred in the running and operating of the plant on a recurring basis. Annual costs include items such as:

- Property taxes and insurance
- Labor for operation and maintenance – labor would include filling the fuel hopper and cleaning out ash
- Parts for annual maintenance and repair
- Administrative costs
- Fuel costs

*Staffing*

The operational requirements, fuel requirements, staffing, etc., for both the KMW® systems and the Hurst systems are very similar, and the staffing requirements for a 1 Megawatt system should not differ from model brands. The modular systems can be very heavily automated, which minimizes the amount of staffing that would be needed to operate the units.

How the plant is owned/operated has a big impact on staffing and other operational requirements. Some options are:

- Utility Owned Facility
- Community or Cooperative Owned Facility
- Independent Business Owned Facility

Staffing for the biomass plant will depend on staffing for other functions that any of the above entities currently have at or near the facility. If this is an independent facility with no other linkage, the staffing costs will be much higher as opposed to a shared workforce. This is because many of the functions of the staff at the biomass plant will involve checking gauges and meters to make sure the system is functioning within acceptable parameters.

Depending upon individual state regulations/requirements, a biomass cogeneration plant may or may not require a licensed steam engineer on site during all hours of operation. It is recommended that in lieu of a licensed engineer, at least one watch person be assigned to the plant each shift to oversee the operation.

In all likelihood, a plant will have to have two to three individuals on site during all hours of operation. A steam engineer or watch person plus staff needed for wood fuel control would be a minimum requirement. To cover a 24/7 operation a biomass plant would probably be looking at staff requirements in the range of 10 to 12 people. Generally, the smaller systems would best fit in at facilities that have personnel present.

Biomass plants could be located at sites or facilities that already have technical staff; therefore, the staff of the biomass plant could be blended into the personnel mix that already exists. Hospitals, correctional facilities, universities, waste treatment centers, recycling centers, food processing facilities, etc. would all have dedicated personnel on site. In many cases, existing personnel could accomplish routine maintenance or fuel preparation functions. In other cases, additional personnel would have to be added. Personnel are a key item that must be clearly understood and accounted for when planning a biomass cogeneration operation Personnel costs have to be controlled.

**Maintenance Requirements**

The modular biomass cogeneration systems can be largely automated in regards to operation as well as maintenance (i.e. the ash removal on these systems can be completely automated).

The manufacturer or supplier will provide detailed instructions for routine operation and maintenance (make sure any changes that are implemented to fit specific requirements of the facility staff are discussed with the manufacturer to ensure the system performance will not be adversely affected or any component warranties voided).[i]

*Regular Maintenance*

The primary maintenance requirements to be performed on a daily basis are intended to monitor the integrity of the fuel going into the combustion system, and to monitor the quality of the water going into the system.

A boiler system requires a proficient watch person to perform a perpetual visual inspection. The visual inspection is the basis of a prevention program's first line of defense against major malfunctions.

*Periodic Maintenance*

Most biomass systems will schedule two periods of formal maintenance each year. Generally, a spring shut down and an autumn shut down are scheduled to perform all critical maintenance necessary for the entire equipment array. Usually a week of shut down during each period will take care of most maintenance issues. If multiple units are present, one or more systems could be operational while one system is being serviced. This formal maintenance is typically subcontracted to professionals that perform boiler and turbine maintenance on a regular basis. The contractors have the skill sets and the personnel to do the job in a timely fashion. Also, the contractors should be approved by the manufacturers to perform the work if there were any warrantee issues.

In addition to daily monitoring and other required tasks, there are regular maintenance tasks that are performed on a periodic basis that may vary from weekly, monthly, or yearly, which can include[i]:

- Boiler tube cleaning
- Mechanical component lubrication
- Inspection and adjustment of chains, gearboxes, blowers, etc.
- Refractory inspection and repair
- Testing of safety devices
- Checking for leaks or air infiltration
- Inspection of insulation and cladding

The system operator, general on-site maintenance staff, dedicated maintenance crew, or contractors from an outside maintenance and service firm can carry out routine maintenance.

*Cost*

A general rule of thumb used in the biomass industry is to set aside one penny per kilowatt (kW) generated annually for maintenance costs, examples:

A 1 Megawatt system (1000kW) operating 8,000 hours per year should have $80,000.00 set aside for maintenance purposes. A 2 Megawatt system (2000kW) operating 8,000 hours per year would set aside $160,000.

If not all of these funds are needed, they could be placed into a contingency account that could grow over the course of operation. In that way, a fund could be created to augment the costs for any major overhaul work or replacement that may have to occur as the system ages.

*Assistance*

Most manufacturers offer technical assistance to their customers and will offer support on a regular basis if called upon to do so.

**System Output: Electric and Thermal**

*Electrical*

A 1 Megawatt biomass cogeneration system would produce a net of 1 Megawatt (1,000 kW) of electrical power for each hour of operation. The term “net” refers to the fact that the parasitic load of the system (the power needed to run the unit) is factored into the mix and will not take away from the net amount of power being offered either behind the meter or to the utility grid. If a unit is rated to produce 1,000 kW that is what will be available to deliver.

For reference purposes, a 1 Megawatt biomass cogeneration system could produce enough electricity to provide domestic load to a community of 1,000 people. Domestic load does not include commercial or industrial activity that may have high power needs. Domestic load, as a general rule of thumb, averages approximately 1 kW per resident. 2 Megawatts could satisfy the domestic needs for 2,000 people, and so on.

*Thermal*

The thermal output made available from a 1 Megawatt biomass cogeneration system could be in the range of 10 million Btu’s of low-pressure steam per hour. The steam could be used directly as low-pressure steam or could be converted via a heat exchanger into hot water for potable water or process applications. Being able to utilize as much of the thermal energy created by the cogeneration system effectively, seriously enhances the economics of the project.

Several comparisons for reference purposes can show how much 10 million Btu’s per hour of energy really is. If you assign a value average of $100.00/hour to the 10 million Btu’s of steam (10,000 lbs) over a 4000-hour heating season, you could produce in excess of $400,000.00 in heat benefits.

Natural gas is sold domestically to end users by the therm (100,000 Btu’s). In the Lake States, as of this writing (Sept 2005), a therm of natural gas transmitted and delivered to the end user is averaging over one dollar US. It would take approximately 120 therms to equal 10 million Btu's of heat. The cost of that amount of natural gas would be approximately $120.00/hour.

There are 132,000 Btu's in a gallon of number two fuel oil. It would take over 75 gallons of number two fuel oil to produce 10 million Btu's of heat. Current market values put the cost of that amount of number two fuel oil at over $150.00. If the steam or converted hot water could be used a minimum of 6,000 hours per year you could assign $600,000.00 per year in heat value to the thermal energy.

Designated applications for the thermal energy created by the project should be clearly defined before building or expanding the system. The effective utilization of the thermal energy will make or break the economics of the project.

## Lifespan

### *Expected Lifespan*

A properly maintained biomass cogeneration system should reasonably be able to have a physical lifespan of twenty-five years or more; however, issues such as new technologies that might make the system obsolete or a drastic change/fluctuation in fuel prices/availability could shorten the economic lifespan of the plant. In theory, however, a modular biomass plant can last indefinitely[1] since the components can be replaced as they wear out or deteriorate.

### *Issues Affecting Lifespan*

There are biomass systems in existence in different parts of the country that are in excess of fifty years old. They have been impeccably maintained and have been operated with the utmost care through the years and have performed very efficiently for their owners. Many of the existing systems started as coal burning systems and were retrofitted to take wood waste fuel.

Conversely, there are biomass systems that have been riddled with problems that are just a few years old; many of these problems are due to inattention to maintenance. These systems have not and will not perform as expected until all maintenance issues are resolved. Lack of or improper maintenance could substantially lessen the life of a unit.

Within the area of maintenance, water treatment should be closely monitored, as water quality is a critical factor in all boiler systems. In some areas, water can be used as is, while in other areas a filtration process and/or chemical treatment needs to be in place. The quality of the water is completely dependent on mineral content and contaminant issues.

Economically, if the system has been placed in an area that takes advantage of a supply of feedstock fuel, and if the electrical power and thermal energy created by the system is utilized effectively, the economics should continue to work in favor of the project for the long term.

### *Warrantee*

The manufacturers generally have warrantees (usually for 1 year after the initial firing date of the system) that come with their products. Make certain that the standard components of a supplier's/manufacturer's formal bid is clearly stipulated in the purchase contract[i]. Most give a general warranty with respect to overall operation and performance plus specific guarantees for unique segments of the system. Standard components (motors, gearboxes, pumps, etc.) usually carry the warranty from their individual manufacturer, although the system supplier should guarantee the suitability of the selected items.

## Insurance

There is a probability that modular biomass plant owners will face higher insurance premiums than other types of power plants due to fire hazards (both real and perceived). Some "informed" insurance companies do not invoke a penalty as long as the installation has the required safety controls and is installed to industry standards. Fuel storage systems can have a significant impact on insurance rates. Enclosed storage areas with a large capacity can potentially pose a high fire risk.

The insurance costs should be checked early in the planning process. In most cases, the supplier can usually provide the names of “informed” insurance companies and provide guidance on avoiding high-risk situations.

**Electrical Power**

The cost of the power generated is going to be dictated primarily by the variable cost of the feedstock fuel. The lower the delivered cost of the feedstock fuel, the cheaper the cost of the power generated.

In terms of electrical power and end users, there should be no difference in electrical power obtained from the biomass power plant versus the utility grid in terms of service; it is just another way of producing electricity. Evidently, the power produced by the biomass plant will have to be cost competitive with the rates from the existing electrical power system.

*Internal Use*

Choices can be made to use the power “behind the meter” or as referred to in Canada as “behind the fence”, which means that you are using the power internally, independent of the utility grid. This could mean being used at one facility or several facilities, however the ownership/operational structure is set up. If the unit is in place for one company, then internal use would refer to only that company; however, if the unit is set up to power all companies within an industrial park, all companies utilizing that power would be considered internal use or “behind the meter”.

If the power generated internally can be produced for $0.06 or $0.07 per kW and the host facility is currently paying $0.08 or $0.09 per kW for externally generated electrical power, then using the power generated internally can make very good sense. In actuality, the buy-sell rate that you negotiate with the power company will dictate how the biomass generated electricity is used.

*External Distribution*

Another option is to arrange to sell some or all of the power to the local utility grid. Different states and different utility districts have various purchasing programs in place. The customer service representatives of the local utilities can assist a facility with their different options.

Initially, one should contact the local power company to understand the distribution system. If the system is connected straight to the transmission system (rather than the distribution system), then contact should be made with the owner of the transmission system if it is not owned by the utility in that area. In Wisconsin, for example, the American Transmission Company (ATC) owns the transmission system.

If the system is connected to the local distribution system and the power is being sold to the local utility in its service territory, no scheduling is required, meaning it is not necessary to schedule a time to obtain transmission service for long-range transport of power.

If you intend to sell power to someone outside the local utility territory and the power has to travel over the transmission system, the purchaser has to get transmission service to ensure the power can be delivered in consideration of constraints, etc. For small sources, this can be cumbersome and costly.

In terms of a buyback rate, an existing tariff rate would most likely apply. If the generator has renewable value (i.e. uses wood fuel), a premium may be paid by the power company (purchaser) depending upon their needs to meet any renewable standards that might apply at that time. If the utility is not paying a premium, credits could be sold to national marketers at a negotiated rate.

Interconnection with the grid would most likely be handled on a case-by-case basis. However, if the units are installed in an industrial sector, there is a better chance that the distribution system is more robust and value may be gained by placing the unit closer to load sources.

If there is a minimal need for electrical power on site, but a substantial thermal need on site, selling the power to the utility grid (at least at a break even rate) could help the economics of the project. If the power generation application can cover all costs of the cogeneration (feedstock fuel, operation, maintenance, and amortization) the thermal energy essentially becomes a bonus.

*Operational Factors*

If the thermal energy amounts to a savings of several hundred thousand dollars a year or more, then the system is paying for itself immediately. Again, if the electric portion of the cogeneration covers all costs, the thermal energy is expense free. That is how a cogeneration biomass operation can justify itself.

Profitability would depend on all of the following factors: installed cost, variable operations and maintenance, fixed operations and maintenance, fuel cost, buyback rate, and any renewable premiums. As mentioned earlier, positioning biomass systems in places that already have technical staff present will help to minimize the cost of labor. Controlling feedstock fuel cost is also a critical important factor.

**Thermal Energy**

Ideally, any operation (i.e. greenhouses, drying kilns, district heating) that would be receiving thermal energy from the cogeneration system should be situated adjacent to or as close to the physical plant as possible.

In Europe, particularly in Scandinavia, it is more typical than not to witness a network of commercial greenhouses built adjacent to a biomass power plant. The thermal energy created by the plant is easily transported to the greenhouses, as travel distance for the thermal energy is minimal. Designing a project to maximize both electrical and thermal production is essential.

Electrical cable can be run for long distances, but thermal energy (generally in the form of low-pressure steam) will start to lose its effectiveness if it has to travel very far. Generally, one should try to keep the thermal travel distance well under one mile.

If the thermal energy is directed to an application adjacent to the power plant, the steam and condensate return lines typically can be run overhead via insulated pipes. If the thermal energy has to travel some distance to get to the end user, the lines could be buried in trenches and run underground using insulated piping systems. There are added costs connected with this. That is why it is most economical to plan a system that can utilize the thermal energy as close to the production source as possible.

The cost of running the piping, preparing the trenches, and performing all of the heat exchange processes that would have to be done would be factored into the project financing. Those costs become part of the project.

Low-pressure steam can be used as is for heating or process steam applications. It can also be run into a heat exchanger, creating hot water for a number of different applications, such as: using the boiler stem in a closed loop system used to transfer heat to water in a heat exchanger or directly using steam exhausted from the turbine.

**Fuel Supplies**

The single most critical detail that has to be completely defined is the issue of fuel supply. As previously mentioned, there are various sources of feedstock fuel that can be used in biomass cogeneration systems. Waste wood is a typical source of fuel used in biomass operations. Nevertheless, other fuels can be used.

Waste wood could be augmented with other “opportunity fuels” that may bring a stream of cash along with them. In other words, some fuels have tipping fees that come along with them. The entities that have to get rid of the waste pay the tipping fees. In some cases, due to transportation costs, the tipping fees are enough to cover trucking to the cogeneration facility. In those cases, the fuel becomes zero dollars into the fire (an ideal situation). This type of situation would of course be very site specific.

There could be tipping fees for waste paper, municipal sludge, rubber tires, municipal stumpage waste (tree trimmings, blow down, etc.). There could also be tipping fees available for wood pallets and wooden crates. If an opportunity presents itself that a biomass project could be cash flow positive going into the fire, which would be the best of all scenarios.

The most viable source in many areas is whole-tree chips or logging residue. To use whole-tree chips, for most tree species, you would generally be competing with existing pulpwood markets and delivered prices would be at least $25/ton, and considerably more in most cases. This is due to comparatively high stumpage prices. Conversely, logging residue (tops and branches) is usually much cheaper in regards to stumpage prices, but the cost of handling/extraction is usually much higher than with whole-tree chips. Depending on the type of logging operation and delivery distance, these logging residue chips are usually in the $15-$30/ton range, with the low end of this being for some whole-tree skidding operations relatively close to the delivery site.

If all of the feedstock fuel for the biomass plant has to be purchased and those purchase costs drive up the annual operational expenses, the biomass concept may not be the right one for that particular location. Obtaining as much of the fuel from a wood waste source will definitely improve the economics of the plant.

If feedstock has to be trucked in to the site, the transportation costs to get the fuel to the cogeneration plant are usually significant. The cost of truck fuel continues to rise and therefore, any transportation of biomass fuel that is more than a one-hour distance from the facility should be carefully looked at, the numbers have to work.

*For example purposes:*

A 1 Megawatt biomass cogeneration system as proposed with a 400-psi backpressure turbine generator would require approx 50,000,000 Btu's of feedstock fuel per hour. That would equate to 5 tons of green wood fuel per hour. If the cost of the waste wood fuel were $20 per ton, then the project would have fuel cost of $100 per hour.

$100 per hour fuel to create a net supply of 1,000 kilowatts (1 Megawatt) will reflect in $0.10 per kW in fuel costs alone. Adding amortization, operation, and maintenance to the mix will result in a cost of approx $0.15 per kW to generate the electrical power. Even after backing out the financial benefits of the thermal energy the numbers really would not work in today's marketplace.

The same scenario, taking fuel at $0 per hour, would be able to have a finished cost for electrical power in the $0.05 to $0.06 per kW range. This situation would drastically improve the economics of the project. In all likelihood, there would be a mix of fuels with a per hour fuel cost somewhere in between these two scenarios, which will require intense scrutiny of all income and expenses before making a decision.

You have to factor in the average "all in" costs of electricity in the area where the biomass system is proposed. From that point it can be determined if the energy produced is cost competitive or not.

**Potential Availability of Fuel in the Lake States**

In the past, merchantability standards called for a minimum top diameter of four-inches. This standard has been gradually decreasing over time with the advent of improved debarking technology. At this time, a specification of three-inch top for pulpwood is not uncommon, and in many cases, a two-inch top is being adopted by some mills.

******All Estimated Annual Cumulative Figures in charts are from reference[iv] unless otherwise noted***********

## Michigan

**Forested Area**

| | **Total Land Area** (1,000 acres) | **Total Forestland** (1,000 acres) | **Percent Forested** |
|---|---|---|---|
| **Michigan**[v] | 36,358 | 19335 | 53% |

**Estimated Volume of Logging Residue**[ix]
2,641,422 green tons

**MI Logging Residue and Underutilized Species Availability - Stumpage or Cost Assigned by Ownership**
Estimated Annual Cumulative Forest Residues* Quantities (dry tons), by delivered price

| | **< $30/ dry ton delivered** | **< $40/ dry ton delivered** | **< $50/ dry ton delivered** |
|---|---|---|---|
| **Michigan** | 710,000 | 1,034,000 | 1,327,900 |

* Forest wood residues can be grouped into the following categories – logging residue; rough, rotten, and salvable dead wood; excess saplings; and small pole trees.

**Forest Industry Processing Wood Waste**
Estimated Annual Cumulative Mill Residue* Quantities (dry tons), by delivered price

| | **< $30/ dry ton delivered** | **< $40/ dry ton delivered** | **< $50/ dry ton delivered** |
|---|---|---|---|
| **Michigan** | 10,000 | 932,000 | 1,564,000 |

* Mill residues are classified by type and include bark, course residues (chunks and slabs), and fine residues (shavings and sawdust).

**Urban Wood Waste, Industry Recyclables (pallets, crates, etc.) & Construction &Demolition (C&D):**
Estimated Annual Cumulative Urban Wood Waste* Quantities (dry tons), by delivered price

| | **< $20/ dry ton delivered** | **< $30/ dry ton delivered** | **< $40/ dry ton delivered** |
|---|---|---|---|
| **Michigan** | 495,734 | 826,224 | 826,224 |

*Urban Wood Wastes include yard trimmings, site clearing wastes, pallets, wood packaging, and other miscellaneous commercial and household wood wastes that are generally disposed of at municipal solid waste landfills and demolition and construction wastes that are generally disposed of in construction/demolition landfills.

*Policies of Major Landowners*

Federal:
- *Hiawatha National Forest:* Currently, there is not a policy on the utilization of logging residue.
- *Huron-Manistee National Forest:* On fuel reduction timber sales the material that is less than a 4” top is bid in a separate category as part of the lump sum sale process. An average assigned minimum price is $1/cunit or roughly $0.53/ton. On all other timber sales, utilization standards are to a 4” top and the utilization of smaller material is not allowed.
- *Ottawa National Forest:* On sites with poorer soils, leaving logging residue is required. On other sites, logging residue can be utilized as part of the normal timber sale contract and would be included in the lump sum sale price.

State: Lump sum sales are the primary sale method. Bidders purchase the entire tree, therefore no additional stumpage rates will apply because the purchaser already has the option to use the entire tree.

County: There is only one substantial County Forest in Michigan, which currently does not have a stumpage policy on biomass.

Industrial: Varies from owner to owner, many have not addressed the issue at this point, several ownerships are in flux and there are not firm policies as of yet with those ownerships.

Private Non-Industrial: Commercial Forest Reserve Act (CFA) covers both private and industrial land and there is no severance tax on these properties. There really is no need to oversee biomass usage as there is in Wisconsin under the Managed Forest Law (MFL). Many private landowners prefer to have all of the logging residue removed for a more park-like appearance and in many cases, do not receive any additional stumpage for it. In other cases, landowners actually pay to have the logging residue removed.

## Minnesota

**Forested Area**

| | **Total Land Area** (1,000 acres) | **Total Forestland** (1,000 acres) | **Percent Forested** |
|---|---|---|---|
| **Minnesota**[v] | 50,954 | 16,769 | 33% |

**Estimated Volume of Logging Residue**[ix]
4,326,000 green tons

**Forest Industry Processing Wood Waste:**
Estimated Annual Cumulative Mill Residue* Quantities (dry tons), by delivered price

| | **< $30/ dry ton delivered** | **< $40/ dry ton delivered** | **< $50/ dry ton delivered** |
|---|---|---|---|
| **Minnesota** | 71,000 | 916,000 | 1,121,000 |

* Mill residues are classified by type and include bark, course residues (chunks and slabs), and fine residues (shavings and sawdust).

**Urban Wood Waste, Industry Recyclables (pallets, crates, etc.) & Construction &Demolition (C&D):**
Estimated Annual Cumulative Urban Wood Waste* Quantities (dry tons), by delivered price

| | **< $20/ dry ton delivered** | **< $30/ dry ton delivered** | **< $40/ dry ton delivered** |
|---|---|---|---|
| **Minnesota** | 919,517 | 1,532,529 | 1,532,529 |

*Urban Wood Wastes include yard trimmings, site clearing wastes, pallets, wood packaging, and other miscellaneous commercial and household wood wastes that are generally disposed of at municipal solid waste landfills and demolition and construction wastes that are generally disposed of in construction/demolition landfills.

*Policies of Major Landowners*

Federal:

- *Chippewa National Forest*: Logging residue removal has not been a major issue at this point and a policy regarding logging residue removal is not in place.
- *Superior National Forest*: They are currently working on putting a policy together. They are actively engaged in a partnership with several entities using a USFS grant to identify issues and opportunities in regard to biomass utilization from the Superior National Forest.

State: The current stumpage rate being assessed to logging residue as of September 2005 is $2/ton on State timbersales. Minnesota Forest Resources Council (MFRC) guidelines require the retention of some coarse woody debris and snags for wildlife habitat purposes.

County: Policy is variable from county to county. One county has assigned stumpage rate of $2/ton while most counties have not addressed this issue.

Industrial: Varies from owner to owner, many have not addressed the issue at this point, several ownerships are in flux and there are not firm policies as of yet with those ownerships.

Private Non-Industrial: Many private landowners prefer to have all of the logging residue removed for a more park-like appearance and in many cases, do not receive any additional stumpage for it. In other cases, landowners actually pay to have the logging residue removed. From timbersales that we received information on, the range was from $0 - $2/ton. Additionally, the MFRC guidelines recommend that some coarse woody debris and snags be retained for wildlife habitat purposes.

**Logging Residue and Underutilized Species Availability - Stumpage or Cost Assigned by Ownership**

| **Estimated Logging Residue and Underutilized Species Availability:** [vi], [vii], [viii] | |
|---|---|
| Cumulative Timberland Acreage | 14,759,828 tons |
| Estimated Roundwood Harvest (green tons) | 3,700,000 tons |

| | |
|---|---|
| Estimated Harvest Residue Available (green tons) | 1,498,500 tons |

## Wisconsin

**Forested Area**

| | **Total Land Area** (1,000 acres) | **Total Forestland** (1,000 acres) | **Percent Forested** |
|---|---|---|---|
| **Wisconsin**[v] | 34,761 | 15,963 | 45% |

**Estimated Volume of Logging Residue**[ix]

4,368,996 green tons

According to the most recent Wisconsin Wood Residue Study[x], each year the manufacturing sector in Wisconsin disposes of at least 500,000 tons of wood residue, or about one quarter of the residue it produces, costing businesses about $7,000,000.00 annually. Unutilized residue (both pallet and non-pallet) is primarily generated in southeastern Wisconsin although there are sources distributed throughout the state.

**Forest Industry Processing Wood Waste**

Estimated Annual Cumulative Mill Residue* Quantities (dry tons), by delivered price

| | **< $30/ dry ton delivered** | **< $40/ dry ton delivered** | **< $50/ dry ton delivered** |
|---|---|---|---|
| **Wisconsin** | 42,000 | 1,202,000 | 1,920,000 |

* Mill residues are classified by type and include bark, course residues (chunks and slabs), and fine residues (shavings and sawdust).

**Urban Wood Waste, Industry Recyclables (pallets, crates, etc.) & Construction &Demolition (C&D):**

Estimated Annual Cumulative Urban Wood Waste* Quantities (dry tons), by delivered price

| | **< $20/ dry ton delivered** | **< $30/ dry ton delivered** | **< $40/ dry ton delivered** |
|---|---|---|---|
| **Wisconsin** | 383,466 | 639,110 | 639,110 |

*Urban Wood Wastes include yard trimmings, site clearing wastes, pallets, wood packaging, and other miscellaneous commercial and household wood wastes that are generally disposed of at municipal solid waste landfills and demolition and construction wastes that are generally disposed of in construction/demolition landfills.

*Policies of Major Landowners*

Federal: On the Chequamegon-Nicolet National Forest (the only National Forest in Wisconsin), all timbersales are done on a lump sum basis with a utilization requirement to a four-inch top. This means that anything smaller than the four-inch top remains in the ownership of the National Forest. To date, there has been no demand for doing chipping on the National Forest; consequently, there is no system in place for addressing what the cost per ton would be for the removal of this material. There is nothing within the forest plan that forbids this from happening except on poor sites (i.e. coarse sand soil type).

State: Timber sales are bid to variable top diameters. Contractors bid based on their utilization standards. The total sale bid is the determining factor as to which contractor will get the sale.

County: There are 29 County Forests in Wisconsin. Logging residue utilization policy varies tremendously between the 29. In some counties, it has not even surfaced as an issue so there is no policy. On scaled sales, several counties use a percentage addition to the timbersale volume to account for biomass. For Example: if a sale were cruised at a 1,000 cords to a four-inch top utilization, 20% would be added on to come up with 1,200 cords total for this sale. A contractor who was going to utilize the whole tree would put a per cord bid on the 1,200 cords and a contractor who was only going to use the four-inch top would put in a per cord bid on the 1,000. The totals of each bid would then be compared to determine the high bid).

Industrial: This has not been addressed by most of the industrial landowners at this point. In one instance, where the whole-tree chips are going into a pulpmill, the same stumpage price is paid regardless of whether it is to a four-inch top or what is traditionally considered 'logging residue'. In regards to traditional logging residue, there seems to be very little set policy on the part of the major industrial landowners.

Private Non-Industrial: Approximately 20% of all private forestland is under the Managed Forest Law (MFL), and for this program, stumpage rates for fuelwood in the 12 areas of the state range from $5/cord to $13.53/cord. For basswood, the stumpage rates ranges from $2.60/cord to $9.66/cord. The landowner has to pay a 5% severance tax. Based on these rates per ton, these severance tax rates would be approximately $0.11 to $0.29/ton for fuelwood and $0.06 to $0.21/ton for basswood. (Basswood is used as an example because, historically, this species in the pulpwood size class has been hard to market and could potentially be an excellent biomass fit.)

For individuals not under the Managed Forest Law (MFL), many prefer to have all of the logging residue removed for a more park-like appearance and, in many cases, do not receive any additional stumpage for it. In other cases, landowners actually pay to have the logging residue removed.

**Potential need for Modular Biomass Systems in the Lake States**

One of the areas in North America that may be best suited for modular biomass systems, with all of its potential benefits, would be the Lake States region of the United States. The states of Michigan, Minnesota, and Wisconsin have concentrations of forest product related activities as well as numerous agricultural operations. Biomass fuel may be readily available in many areas of the Lake States region. In addition, due to its cold climate, the Lake States region has one of the longest heating periods in the country. That fact works well when you are looking to use thermal energy in a productive manner.

Wood processing activities can be extremely energy intensive. A wood fired biomass system could provide the electrical needs to operate a sawmill operation and provide the thermal energy needed to heat a dry kiln that could be part of the facility.

Within communities, the opportunity for modular biomass plants could be excellent for industrial parks, community facilities, etc. The option of biomass systems having commercial greenhouse facilities on-site is also an excellent fit.

The opportunity for community based modular biomass systems is as strong, if not stronger, in the Lakes States than any area of the country outside of Northern New England.

**Special Use Opportunities**

A potential use for a modular biomass power plant would be in areas that have a sudden availability of potential woody biomass fuel. This would include areas that have had storm damage, insect/disease damage, fire damage, etc. In situations like this, where large quantities of potential woody biomass fuel become available, establishing a modular biomass power plant and selling power into the local grid system could potentially be the best economic use of the wood that is made available by these events. In this type of situation, it might be difficult to utilize the thermal energy, therefore equipping the plant with a condensing unit and converting all of the biomass energy into electricity would probably be the best option. This of course would be dependent upon the capacity to harvest the wood and convert it into chips as well as evaluating the economics of the buyback rate for the electricity generated. (Appendix 3)

Since this modular system can be transported in five to eight pieces, it could be moved from area to area depending on where it was needed and the amount of fuel available. Potentially, it could be placed in an area for one to three years, the amount of time being dependent on fuel availability and the need for the unit elsewhere. The building that would be needed to house the unit could potentially also be made portable to be moved with the unit and all that would be needed on-site would be a cement pad, a water source, and easy access to the existing electricity grid system.

This type of system could also be very viable in other parts of the country, particularly in areas that have frequent natural disasters, such as hurricanes in the southeastern US and major forest fires in the western US.

**Cost Estimate**

The following is a generic estimate of what a simple 1 Megawatt biomass cogeneration facility could cost. Pricing is based on equipment estimates as of September 2005. Prices listed are for equipment completely installed. The cost of a building and site preparation are not included. The pricing is meant merely as a guideline and can differ from project to project.

**1 MW BIOMASS COGENERATION FACILITY**

***Plant Design:***

| | |
|---|---|
| Electrical Output (net) | 1000kW |
| Thermal Output (net), low pressure steam and/or future hot water | 35 MM Btu |
| Fuel-Biomass | 1.5”X2.5”X5/8” or less in size |
| Fuel Consumption @50%MC | 4347 Btu/lb -13,500 lb/hour |
| Btu Input | 58,684,500 Btu/hour |
| Fuel Storage | 300 Tons |

*System Description:*

Wood Fired Steam Boilers, 600 hp (20,700 lbs/hr) 400psi, saturation

Biomass Boiler System $1,900,000.00

*Included Packaged System Components:*

Built in accordance with ASME, the boiler (water tube/fire tube) is an excellent and economical design for this application. The boilers water tube section allows for abundant radiant heating surface while the fire tuber section allows for greater water volume and thermal reserve. With a conservative design rating at no less than 6.5 sq ft. of heating surface per boiler horsepower, the boiler package is equipped with a revolving grate stoker and automatic ash removal, making these boiler ideally suited for electric cogeneration.

*The biomass boiler package includes:*

- Furnace and boiler
- Metering Bin w/Variable Frequency Drive (Also known as VFD, it is an energy saving feature)
- Automatic traveling grate stoker
- Combustion and over-fire air fans w/VFD’s
- Two (2) mechanical collectors w/rotary air locks
- Induce draft fan w/VFD
- Ash transfer conveyors and ash totes
- Instrumentation and controls

*Stack*

- 60’ free standing

*Water Treatment System*

- Filters/softeners
- Condensate receiver
- Deaerator and duplex feed water pumps
- Blowdown tank
- Chemical feed system
- Balance of Plant
- Compressed air system
- Duplex fresh water supply pumps

*System Description:*

1200 kW Turbosteam or equal T/G Set, Backpressure design

Steam Turbine/Generator Set: $800,000.00

This economical single stage, backpressure turbine with a 480 v synchronous generator is equipped with controls to maintain exhaust (process) steam pressure precisely at operator-definable set point. This plant is configured to include an air condenser to condense excess exhaust steam, allowing for full power generation with varying process flows.

*The turbine generator package includes:*

- Turbine
- Generator
- Gear reducer
- Lubrication system
- Switchgear/relaying
- Instrumentation and controls
- Air condenser package

The proposed "all in" costs for the boiler system, turbine system, and all ancillary equipment are approximately $2.7 million.

A 1 Megawatt system, as proposed, would produce a net of 1000 kW per hour. If set up to run a minimum of 7000 hours per year, the system could produce approx. 7 million kWh per year. If a facility averages electrical power costs in the $0.08 or $0.09 range, the cogeneration could offset approximately $500,000-$600,000 worth of electrical costs annually. At the same time, a conservative estimate of thermal energy value is at least $500,000 per year when compared to natural gas or oil.

With the right amortization schedule, the right fuel procurement in place, and proper management, a small biomass cogeneration system could be cash flow positive during its first full year of operation.

If the cost of the feedstock fuel is substantial, the biomass plant economics become more tenuous. Profitability is directly related to the cost of alternative fuels. This, however, is not an absolute. Factors such as high local energy costs, renewable energy credits, more complete usage of thermal energy, etc. could also make the project more economical.

**Case Studies**

*Case Study #1 (provided by KMW®)*

Sawmill Turns Waste into Electric Power and Thermal Supply (*The size and scope of this project is very much in line with the proposed 1 Megawatt modules that have been discussed in this study)*

Taylor Lumber Co. Ltd. located in Middle Musquodoboit, Nova Scotia employs between 60-80 people and produces 8-10 million board feet per year of kiln dried and heat-treated lumber. The mill began its operation in 1946 with the sawing of rough lumber and in later years developed a planing mill operation to finish the lumber to greater tolerances.

In the early 1990's it became apparent that kiln-drying lumber was a profitable process. When the company decided to expand in 1993, sawing capabilities increased. The expansion also included a KMW® wood-fired biomass cogeneration plant that would produce both electrical power and thermal energy in the form of low-pressure steam.

The purpose of the cogeneration plant would be to provide all of the electrical power needed to operate the wood mill, and all of the steam needed to run the drying kiln. Any surplus electrical power would be sold to the local electrical utility.

When the newly expanded sawmill was completed, the production of biomass fuel was increased to 90% of the power plant's need, with the balance being trucked in. The new boiler produces 20,000 lbs of steam per hour, which generates over 1,000 kW (1 Megawatt) of electrical power. The system also provides all of the thermal energy needed to heat the dry kilns.

The benefit of the KMW® wood-fired biomass cogeneration system is not only a safe disposal of the mills wood waste but it also improves the company's profitability.

*Case Study #2 (provided by Hurst)*

Another Sawmill Energy System *(The size and scope of this project is smaller than the proposed 1 Megawatt system but it is an excellent example of how the systems can be utilized)*

King Forest Lumber in Wentworth, New Hampshire is an operational sawmill and lumber drying facility. The company installed a single 600 HP Hurst wood-fired high-pressure boiler/back pressure turbine array to help defray energy costs. The 750kW (3/4 Megawatt) provides approximately half of the electrical power needs of the facility. The thermal energy provided by the cogeneration operation heats the wood drying kilns that are adjacent to the cogeneration plant.

The King Forest project is an excellent example of how the modular system concept came to the forefront and was able to address sensible wood waste disposal, creation of affordable electrical power, and creation of affordable thermal energy. If set up and managed properly, these systems demonstrate that they make economic and environmental sense for the long-term.

## Other Biomass Applications

The technology that has been featured in this study is centered upon companies that manufacture hybrid combustion biomass boiler systems. The high-pressure steam that is produced from these systems would be directed to a back pressure turbine for the creation of electrical power. The low-pressure steam that would be left over from the process could be directed to a variety of thermal energy needs (space heating, hot water production, etc.).

There are other biomass technologies in the marketplace that are used to cogenerate energy.

*Gasification Systems*

Gasification systems are available that would produce a pyrolytic gas from biomass material. The pyrolysis occurs in a chambered system that is separate from the main boiler. In a sealed atmosphere, the pile of biomass material is "baked down" inside of the chamber and eventually emits a pyrolytic gas. The pyrolytic gas is then injected into the boiler system. No biomass material goes directly into the boiler with a gasification system in place. It can be a very clean and efficient process.

Generally, gasification systems can be very material sensitive and are not as forgiving towards a mixture of biomass fuels as a hybrid combustion system would be which could limit the options at hand regarding fuel choices.

Additionally, gasification systems are going to add serious costs to the project. The whole idea of keeping this simple is to put a series of affordable, easily managed, easily maintained units on line that are capable of utilizing a variety of waste feedstock fuels. Gasification systems belong in a different category.

*Merchant Power Plants*

If a community was interested in putting together a 5 Megawatt or larger biomass power plant right from the start there would be a number of options that they could explore that would be different from what has been discussed in this study.

Systems larger than 5 Megawatts would be custom built on the job site. Rather than a series of backpressure turbines, a larger facility may choose to have one primary condensing turbine to produce electricity. The costs of such an expanded effort are greater, but if planned properly they can work very dependably and affordably for many years.

**Summary**

Modular biomass plants are one way of putting an efficient, cost effective renewable energy system on line in an affordable and sustainable manner. By no means is the information definitive as there are numerous applications that could be put on line to utilize biomass feedstock fuel in a productive manner. The modular concept could fit into a number of commercial, community, or combination applications.

There is a future for biomass in the coming decades. Biomass energy systems will be able to provide long-term, reliable energy from renewable sources that could blend in wonderfully with a number of energy scenarios. Biomass energy production can be a growing part of the national answer to energy demand and it can be *the* answer on a local level.

Remember, “The relationship is circular: people can’t achieve economic strength without a healthy environment, and they won’t care as much about the environment if they don’t have jobs and dollars. We need to be equally concerned about the economic well-being of our population and our communities, and the well-being of our environment.”[xi]

# APPENDIX

## Appendix 1[xii]

**Production Tax Credit for Renewable Electricity Generation:** *Biomass Provisions in the 2005 Energy Bill*

Section 1301. This provision extends the existing tax credit for electricity generation for "open loop" biomass (wood or other biomass derived from forestry, logging, land clearing) from for two years; facilities must now be placed in service (operating) by December 31, 2007 in order to qualify for the tax credit. The tax credit is for 0.0075 per kWh in 1993 dollars, or roughly $0.0090 in today's dollars. New facilities may utilize the tax credit for ten years though facilities in operation prior to October 22, 2004 may use the tax credit for only five years. Facilities co-firing with fossil fuels are not eligible for this tax credit. Other renewables, such as closed-loop biomass (dedicated energy crops), qualify for this tax credit. The rate for these other facilities is $0.0158 per kWh in 1993 dollars.

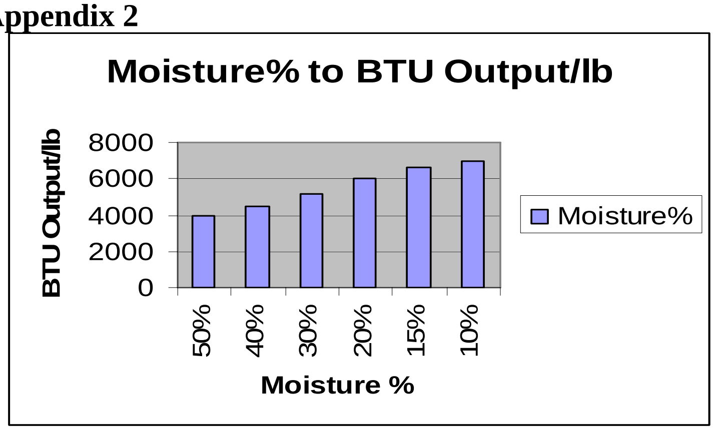
**Grants to Improve the Commercial Value of Forest Biomass for Electric Energy, Useful Heat, Transportation Fuels, and Other Commercial Purposes**

Biomass Commercial Use Grant: Grants are provided in this section to offset a facility's cost of purchasing biomass, up to $20 per green ton. There is no limit on the amount any facility can receive. Important restrictions apply, including:

- Only for non-merchantable biomass (in other words, wood that could not be used for a higher value product) or pre-commercial thinnings that are used to reduce fuel load, reduce or contain an insect and disease infestation, or restore forest health.
- For use in "preferred communities", located in or near federal (or tribal) land with serious fire of forest health concerns and with populations of less than 5,000; and
- Applicable to facilities that use biomass to produce electricity, sensible heat or transportation fuels.

## Appendix 2

| Wood Chips Moisture Content % to Btu Output/Pound | |
|---|---|
| **Green Moisture Content %** | **Btu's/LB** |
| 50% | 4000 |
| 40% | 4500 |
| 30% | 5200 |
| 20% | 6000 |
| 15% | 6600 |
| 10% | 7000 |




## Appendix 3

**2005 Representative Energy Costs**

| Energy Source | Cost in common unit of measure | Cost per million Btu |
|---|---|---|
| Electricity[xiii] | 9.06 cents / KWh (kilowatt hour) | $26.55 |
| Natural Gas [xiii] | $1.09 / therm (100,000 Btu) or $11.23 / MCF (1,000 cubic ft.) | 10.92 |
| No. 2 heating oil [xiii] | $1.76 / gallon | 12.68 |
| Propane [xiii] | $1.55 / gallon | 16.94 |
| Kerosene [xiii] | $2.20 / gallon | 16.32 |
| Mill Residue [i] | $10/ton | 1.68 |

| | | |
|---|---|---|
| Logging Residue [i] | $40/ton | 6.73 |

# GLOSSARY

| | |
|---|---|
| "Behind the Meter" | A closed-loop system in which electricity used within the facility in which it is created, or using the power internally, independent of the utility grid. |
| Back Pressure Turbine | Back pressure turbines are systems that are designed to produce electrical power by reducing high pressure steam and turning the energy into electricity. |
| Biomass | Tree and other plant materials |
| Boiler System | A boiler is a closed vessel in which water or other fluid is heated under pressure. The steam or hot fluid is then circulated out of the boiler for use in various process or heating applications. A valve is required to prevent over pressurization and possible of a boiler. |
| British Thermal Unit (BTU) | Unit of heat equal to the amount of heat required to raise one pound of water one degree Fahrenheit at one atmosphere pressure; equivalent to 251.997 calories |
| Chillers | Chillers are cooling units that produce chilled water that is then used to air condition warm spaces. Chillers are most prevalent in large commercial or industrial operations. |
| Cogeneration | A production of electricity and useful thermal energy simultaniously from a common fuel source. The rejected heat from industrial processes can be used to power an electric generator. Surplus heat from an electric generator can be used for industrial processes, or for heating purposes. |
| Construction & Demolition Debris | Construction and demolition (C&D) debris is produced during new construction, renovation, and demolition of buildings and structures. |
| District Heating | District heating is the process of using a central source of energy (steam) to distribute heat within a residential or commercial neighborhood. The district heating system frees each individual building from having to operate its own heating system. |
| Domestic Load | A typical residential electrical load profile is generally referred to as domestic load |
| Dry Kilns | A kiln for drying and seasoning lumber |
| Feedstock Fuel | Raw material used in boiler systems. |
| Gasification Systems | A gasification system typically will convert biomass feedstock into a pyrolytic gas. The pyrolytic gas created from the gasification system can then be used as fuel for a gas boiler systems, turbines, or engines. They are usually chambered systems that are coupled to high-pressure steam boilers. |
| Heat Exchanger | Heat exchangers are devices that convert one source of heat into another form of heat (i.e. steam exchanged into hot water, or hot air exchange into hot water). |
| High Pressure Steam | High-pressure steam systems are generally systems that run above 15 psi in operating pressure. |
| Hydrocarbon | Chemicals consisting entirely of hydrogen & carbon; can contribute to air pollution problems like smog. |
| Logging (Harvest) Residues | Include both the unmerchantable part of the main stem section of trees that are harvested to produce sawtimber or pulpwood for forest products mills (i.e. merchantable trees) as well as limbs of merchantable trees. In addition, a portion of whole trees could be considered for energy use due to poor form, small size, or undesirable species. |
| Low Pressure Steam | Low-pressure steam systems are generally systems that run at 15 psi or below in operating pressure. |
| Modular | Constructed with standardized units or dimensions allowing flexibility and variety in use |
| Moisture Content | Moisture content expressed on a wet weight basis (also called "green" or "as fired" moisture content) is the decimal fraction of fuel that consists of water. |
| Municipal Sludge | Semi-liquid residue remaining from the treatment of municipal water and wastewater. |
| Potable | Water that is safe to drink. |
| PSI | A unit of pressure, pounds per square inch |
| Renewable Energy | Any energy source that is naturally occurring and that cannot in theory be exhausted, e.g. solar energy, tidal, wind or wave power, geothermal energy, biomass energy. |
| Thermal Energy | ▪ Thermal energy is quantified by temperature (*e.g.*, the physical property of a system which underlies the common notions of "hot" and "cold"; material with the higher temperatures are said to be "*hot*"). |
| Utility Grid | **Utility:** A corporation, person, agency, authority, or other legal entity or instrumentality aligned with distribution facilities for delivery of electric energy for use primarily by the public. Included are investor-owned electric utilities, municipal and State utilities, Federal electric utilities, and rural electric cooperatives. A few entities that are tariff based and corporately aligned with companies that own distribution facilities are also included.<br>**Grid:** A system of synchronized power providers and consumers connected by transmission and |

| | |
|---|---|
| | distribution lines and operated by one or more control centers. In the continental United States, the electric power grid consists of three systems: the Eastern Interconnect, the Western Interconnect, and the Texas Interconnect. |
| Waste Paper | Paper discarded as worthless or useless. |

**Conversion Factors[xiv]:** Average Energy Content of Various Fuels

| | |
|---|---|
| 1 kilowatt hour of electricity | 3,413 Btu |
| 1 cubic foot of natural gas | 1,008 to 1,034 Btu |
| 1 therm of natural gas | 100,000 Btu |
| 1 gallon of liquefied petroleum gas (LPG) | 95,475 Btu |
| 1 gallon of crude oil | 138,095 Btu |
| 1 barrel of crude oil | 5,800,000 Btu |
| 1 gallon of kerosene or light distillate oil | 135,000 Btu |
| 1 gallon of middle distillate or diesel fuel oil | 138,690 Btu |
| 1 gallon of residual fuel oil | 149,690 Btu |
| 1 gallon of gasoline | 125,000 Btu |
| 1 gallon of ethanol | 84,400 Btu |
| 1 gallon of methanol | 62,800 Btu |
| 1 gallon of gasohol (10% ethanol, 90% gasoline) | 120,000 Btu |
| 1 pound of coal | 8,100 to 13,000 Btu |
| 1 ton of coal | 16,200,000 to 26,000,000 Btu |
| 1 ton of coke | 26,000,000 Btu |
| 1 ton of wood (green moisture content of 40%-0%) | 9,000,000 to 17,000,000 Btu |
| 1 pound of low pressure steam (recoverable heat) | 1,000 Btu |

**Measurement Conversions:**

| |
|---|
| 1 short ton (ton) = 2,000 pounds = 6.65 barrels (crude oil) |
| 1 metric ton (tonn) = 2,200 pounds |
| 1 barrel (bbl) = 42 gallons= 5.615 cubic feet = 159.0 liters |
| 1 Mcf = 1,000 cubic feet |
| 1 therm = $10^5$ Btu = 1,000,000 Btu |
| 1 thousand Btu (MBtu) = 1,000 Btu |
| 1 million Btu (MMBtu) = 1,000,000 Btu |
| 1 quad = $10^{15}$ (quadrillion) Btu or 1,000,000,000 MMBtu |
| 1 kilowatt-hour (kWh) = 1,000 watt hours |
| 1 megawatt-hour (MWh) = 1,000 kWh or 1,000,000 watt-hours |
| 1 gigawatt-hour (GWh) = 1,000 MWh or 1,000,000,000 watt-hours |
| 1 gallon = 4.524 pounds liquefied petroleum gas |

# REFERENCES


[i] CANMET Energy Diversification Research Laboratory and by SGA Energy Limited, for the Renewable and Electrical Energy Division, Energy Resources Branch, Natural Resources Canada, *Buyers Guide to Small Commercial Biomass Combustion Systems*, 2000.

[ii] The use of trade names or references to specific companies or products in this publication does not imply endorsement; they are intended only as an aid to the reader.

[iii] The use of trade names or references to specific companies or products in this publication does not imply endorsement; they are intended only as an aid to the reader.

[iv] Walsh, Marie E.; Perlack, Robert L.; Turhollow, Anthony; Torre Ugarte, Daniel de la; Becker, Denny A.; Graham, Robin L.; Slinsky, Stephen E.; and Ray, Daryll E.; *Biomass Feedstock Availability in the United States: 1999 State Level Analysis*, Oak Ridge National Laboratory, Oak Ridge, TN; University of Tennessee, Knoxville, TN; Science Applications International Corporation, Oak Ridge, TN, April 30, 1999, Updated January, 2000

[v] Hodgetts, Rachel and Freese, Roseanne, *An Economic Overview of the Unites States Solid Wood Industry*, http://www.fas.usda.gov/ffpd/Economic-Overview/area_stock.pdf

[vi] Berguson, Bill; Buchman, Dan; Maly, Craig; *Analysis of Forest Harvest Residue Availability for the Laurentian Energy Authority*, Natural Resources Research Institute (NRRI), Duluth, MN, February 28, 2005

[vii] Grigal, D.F. 2004. *An Update of Forest Soils, A Technical Paper for a Generic Environmental Impact Statement on Timber Harvesting and Forest Management in Minnesota*, David F. Grigal – Forestry/Soils Consulting. 32 p.

[viii] Jenkins, J.C., Chojnacky, D.C.; Heath, L.S.; Birdsey, R.A.: 2004 *Comprehensive database of diameter-based biomass regressions for North American tree species.* USDA Forest Service, General Technical Report NE-319. 45 p.

[ix] United States Department of Agriculture, Forest Service. 2005. Forest Inventory and Analysis, North Central Research Station, St. Paul, MN

[x] Everson, Vern A. and Hubing, Nicholas R., *Wisconsin Wood Residue Study: Wood Residue from Manufacturing Excluding Sawmills*, October 1993, Wisconsin Department of Natural Resources Bureau of Forestry, Publ-FR-075-93

[xi] Youngquist, John A. – Project Leader and Hamilton, Thomas E. – Director, *The Next Century of Wood Products Utilization: A Call for Reflection and Innovation*, USDA Forest Service, Forest Products Lab., Madison, Wisconsin, USA

[xii] Kinglsey, Eric Innovative Natural Resource Solutions, LLC – *In Brief… Biomass Provisions in the 2005 Energy Bill*, 2005. Portland, ME

[xiii] Department of Energy, Office of Energy Efficiency and Renewable Energy, *Energy Conservation Program for Consumer Products: Representative Average Unit Costs of Energy*, Office of Energy Efficiency and Renewable Energy, Department of Energy, 2005, http://a257.g.akamaitech.net/7/257/2422/01jan20051800/edocket.access.gpo.gov/2005/pdf/05-4768.pdf

[xiv] Data Collected from: http://www.baywinds.com/new/Conversion%20Factors.doc